



INVESTIGATION OF ORTHORHOMBIC-HEXAGONAL PHASE TRANSITIONS IN HIGHLY SUBSTITUTED $\text{Lu}_{1-x}\text{Sc}_x\text{FeO}_3$ SYSTEM

Andrius Pakalniškis¹, Ramūnas Skaudžius¹, Alexander Zhaludkevich², Anton Turygin³, Denis Alikin³, Dmitry Karpinsky², Aivaras Kareiva¹

¹Institute of Chemistry, Vilnius University, Naugarduko 24, LT-03225 Vilnius, Lithuania

²Scientific-Practical Materials Research Centre of NAS of Belarus, 220072 Minsk, Belarus

³School of Natural Sciences and Mathematics, Ural Federal University, Russia

andrius.pakalniskis@chgf.vu.lt

Introduction

Multiferroic materials are classified compounds that exhibit at least two of the primary ferroic order parameters. Over the last couple of decades, they have been widely studied due to their interesting physical properties. This is especially true for materials with both magnetic and electric orderings [1]. The ability to control magnetic ordering with electric field and vice versa opens a lot of new fields of application. However, for the most part, due to the conflicting nature of these properties, the coupling between the electrical and magnetic properties is relatively weak. Since magnetic properties usually require the 3d layer to be partially filled by electrons, while electrical properties arise from empty 3d shells [2]. To solve this conundrum, materials with new mechanism for the origin of their ferroelectric properties were discovered, such as lone pair and spin driven mechanisms, that do not require empty electron shells. The second issue that multiferroic compounds suffer from is the fact that most orderings only occur below room temperature. Only few room temperature multiferroics are known, with the main research being focused on BiFeO_3 [3].

Recently a new class of hexagonal rare earth ferrite perovskite compounds has been found to exhibit multiferroic ordering, with a mechanism and structure similar to that of hexagonal manganites, making them a new avenue for potential research [3]. However, the in many cases the hexagonal ferrite compounds are relatively unstable due to their expanded lattice. Stabilization of the mentioned hexagonal structure is usually performed by thin film fabrication on some substrates, but the additional strain and interface interactions can cause substantial changes to their intrinsic physical and chemical properties [4]. As such, it is essential to analyze the bulk samples of such materials. One important candidate for further in-depth analysis is Sc doped LuFeO_3 , since via the doping effect it is possible to stabilize the hexagonal structure with a P6cm space group [5]. However, further characterization on the exact compositional ranges and synthesis conditions on the phase formation as well as the effect of dopant on the ferroic properties still needs further research.

Hence, in this work we explore the sol-gel synthesis conditions for suitable preparation of $\text{Lu}_{1-x}\text{Sc}_x\text{FeO}_3$ in the entire concentration range ($0 < x < 1$) and investigate the structural transitions together with particle morphology.

RESULTS

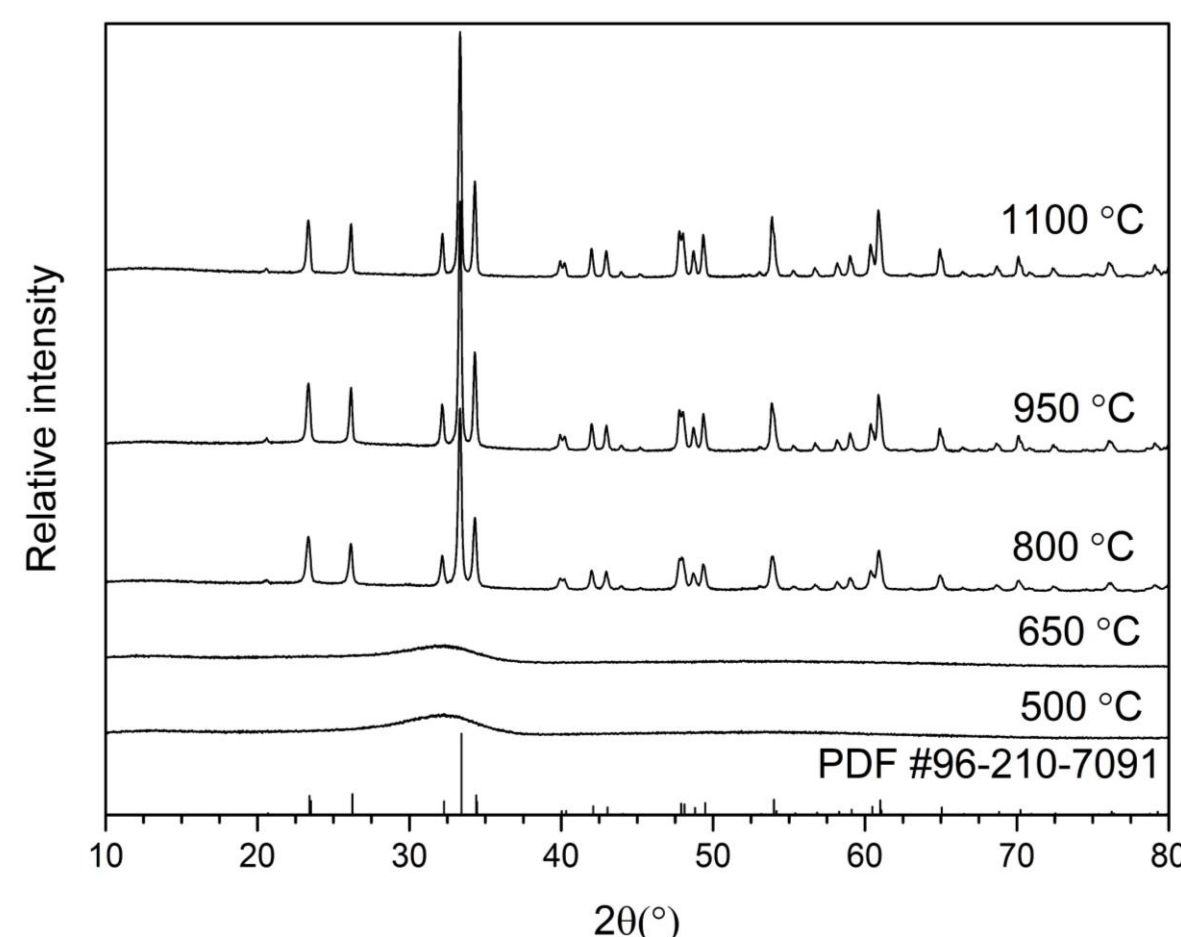


Fig. 1. XRD images of LuFeO_3 samples annealed at different temperatures when using ethylene glycol as a complexing agent

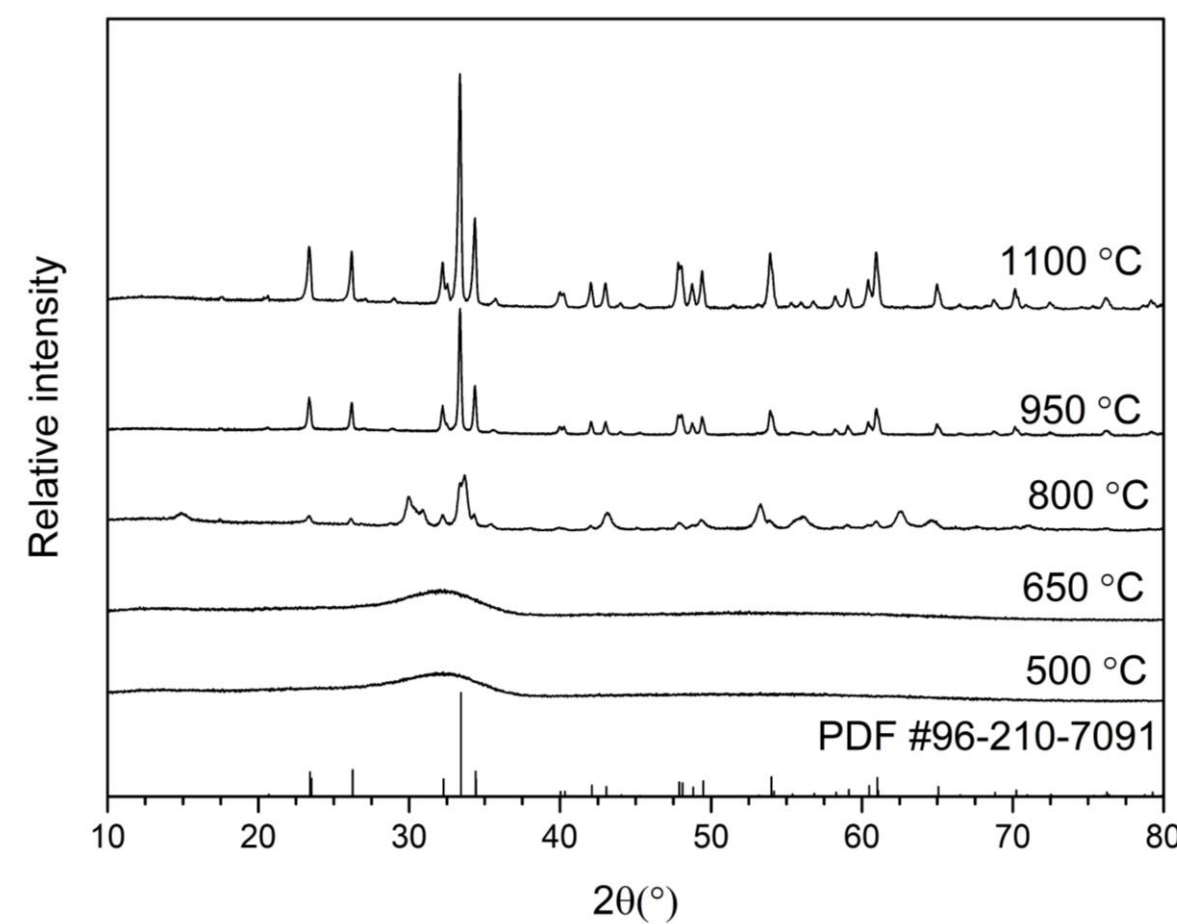


Fig. 2. XRD images of LuFeO_3 samples annealed at different temperatures when using citric acid as a complexing agent

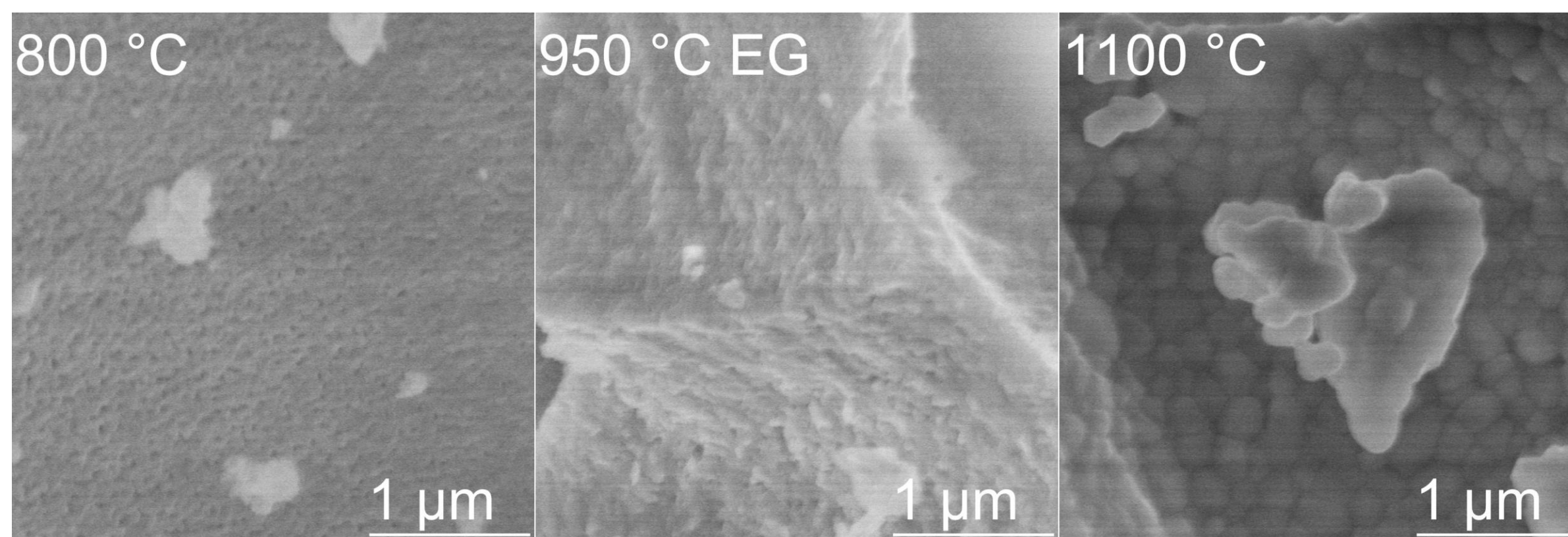


Fig. 3. SEM images of LuFeO_3 samples annealed at different temperatures when using ethylene glycol as a complexing agent

CONCLUSIONS

Based on the obtained results we can conclude that it is possible to obtain single phase LuFeO_3 compound in either doped and undoped state. In the case when preparing undoped compound no formation of impurity phases was observed with ethylene glycol as complexing agent even up to 1100 °C. The perovskite compound shows orthorhombic symmetry and a Pbnm space group. However when using citric acid as a complexing agent at all temperatures above 650 °C secondary phase formation was observed. While using both ligands a formation of amorphous phase occurs up to 650°C. SEM analysis of the samples prepared with ethylene glycol revealed that higher sintering temperature leads to a formation of larger and more distinct grains.

When doping the system with Sc ions several different phase regions were observed. Even at the initial doping amount of 10 %, a mixture between hexagonal and orthorhombic phases was observed. This region extended up to 75 % of Sc, at which a single phase region consistent of hexagonal structure was observed. At 80 % already a mixture of hexagonal and cubic phases was determined. In the region from 85 % to 95 % a mixture of three different phases was measured, namely hexagonal, cubic and rhombohedral. And lastly at 100 % of Sc a single phase cubic structure was observed. However, in this case it was a non-perovskite bixbyite structure. Lastly, SEM analysis revealed that an increase in Sc content reduces particle size, while also compounds in the mixed phase regions showed distinctly different particle morphology as compared to single phase samples.

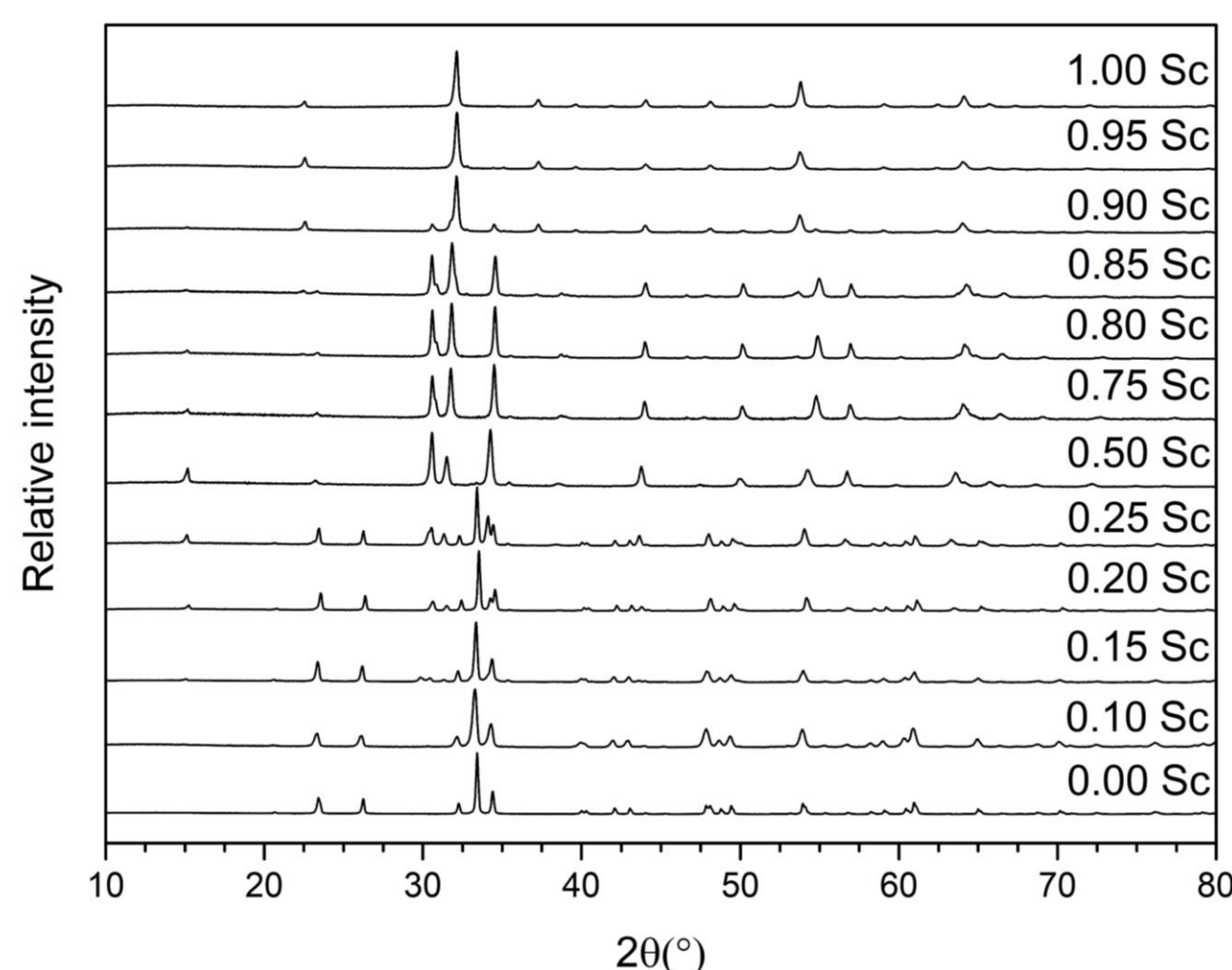


Fig. 4. XRD images of $\text{Lu}_{1-x}\text{Sc}_x\text{FeO}_3$ ($0 \leq x \leq 1$) samples annealed 1100 °C when using ethylene glycol as a complexing agent

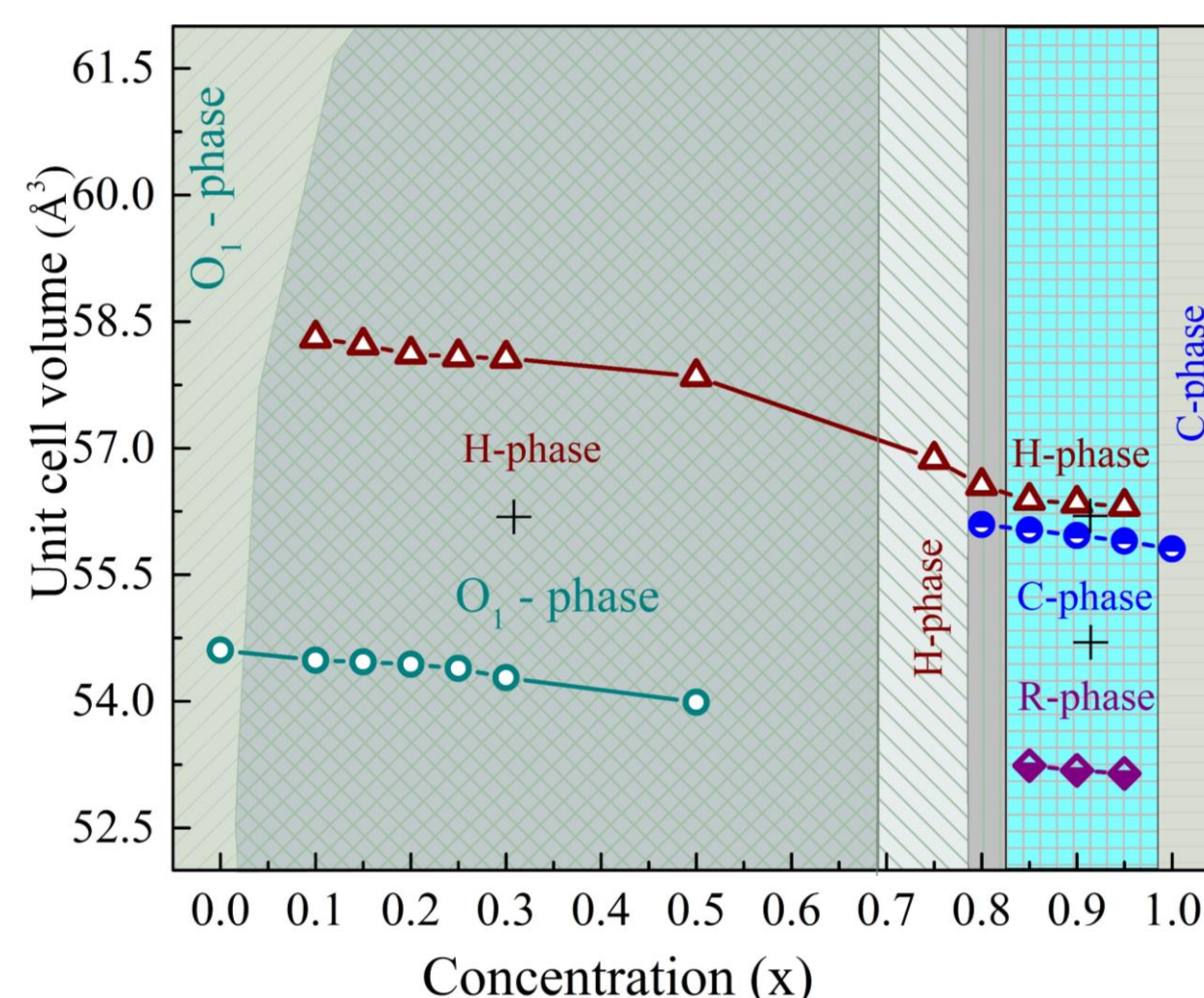


Fig.5. Phase composition diagram of $\text{Lu}_{1-x}\text{Sc}_x\text{FeO}_3$ ($0 \leq x \leq 1$) samples annealed 1100 °C when using ethylene glycol as a complexing agent

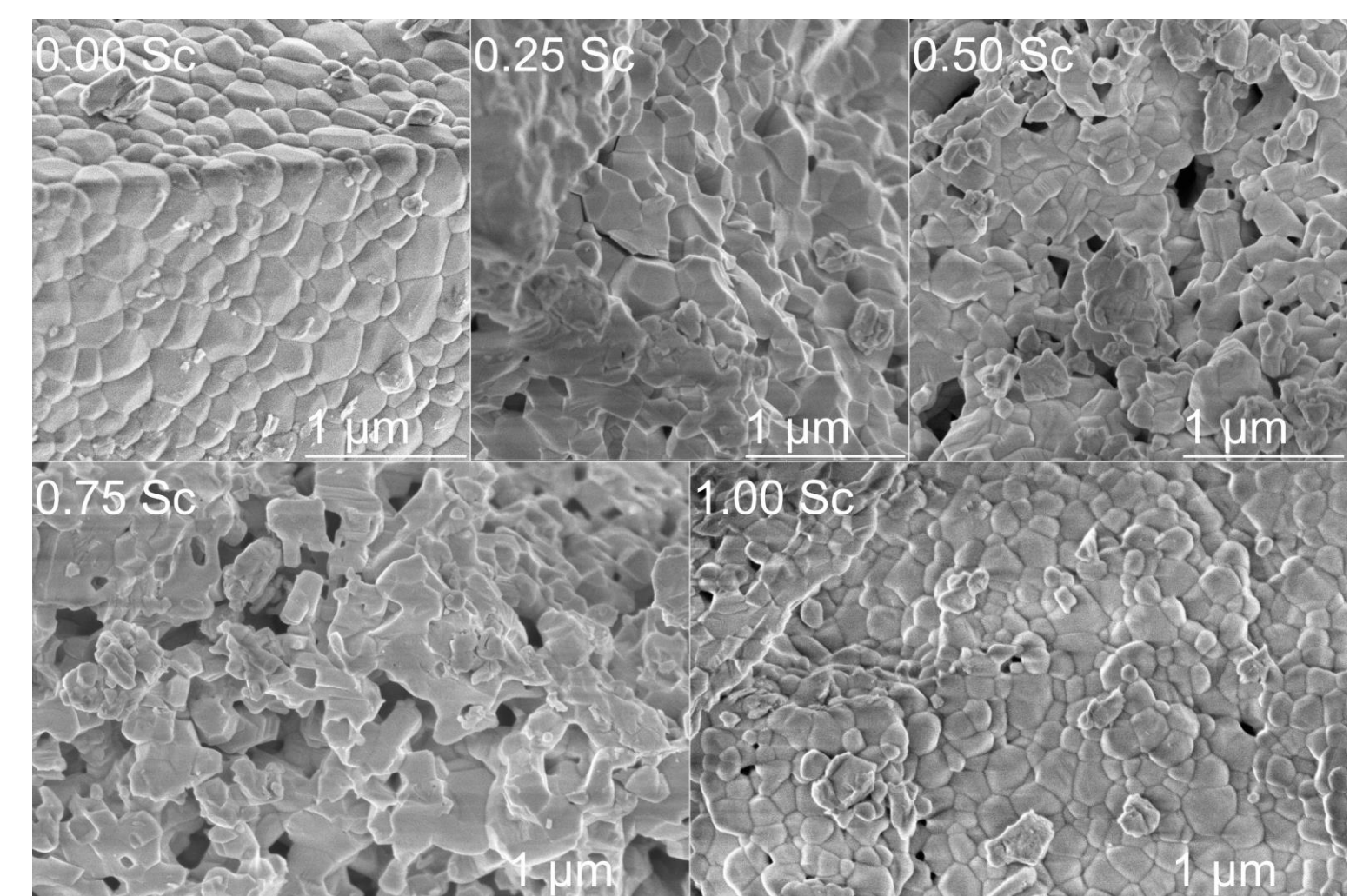


Fig.6. SEM images of $\text{Lu}_{1-x}\text{Sc}_x\text{FeO}_3$ ($0 \leq x \leq 1$) samples annealed 1100 °C when using ethylene glycol as a complexing agent

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